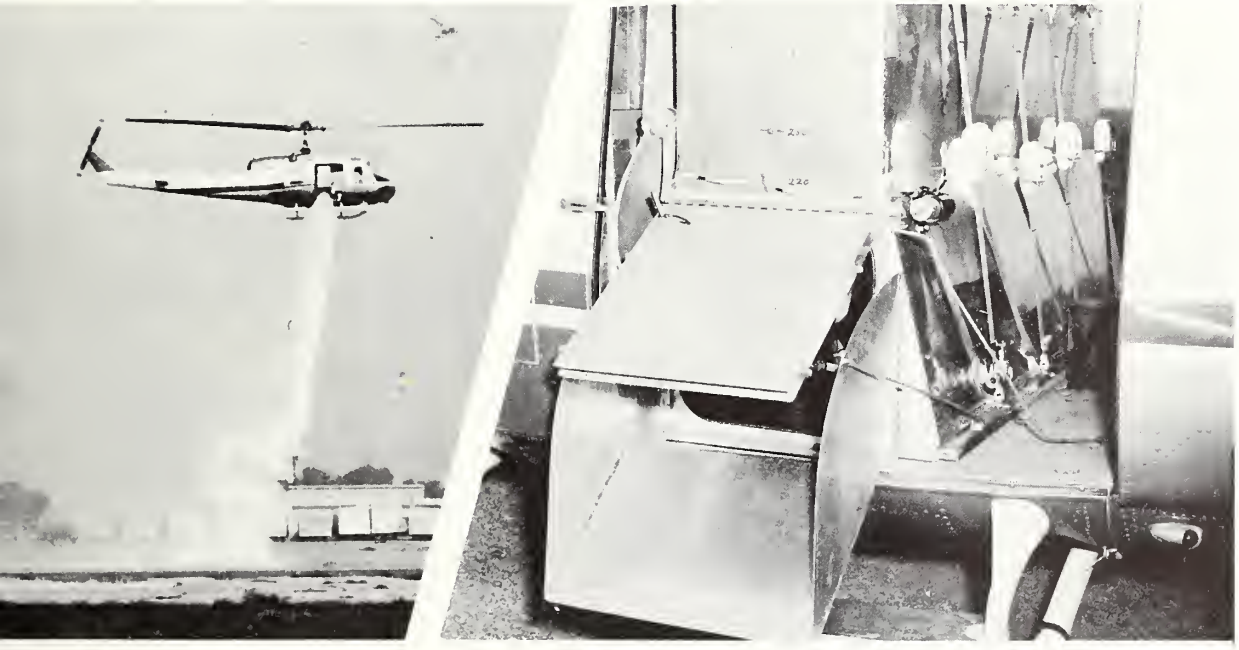
SPECIAL REPORT ED&T 1139

BELL 204 B 360 GALLON HELITANK EVALUATION

FEBRUARY 1964



ARCADIA EQUIPMENT DEVELOPMENT AND TESTING CENTER

FOREST SERVICE
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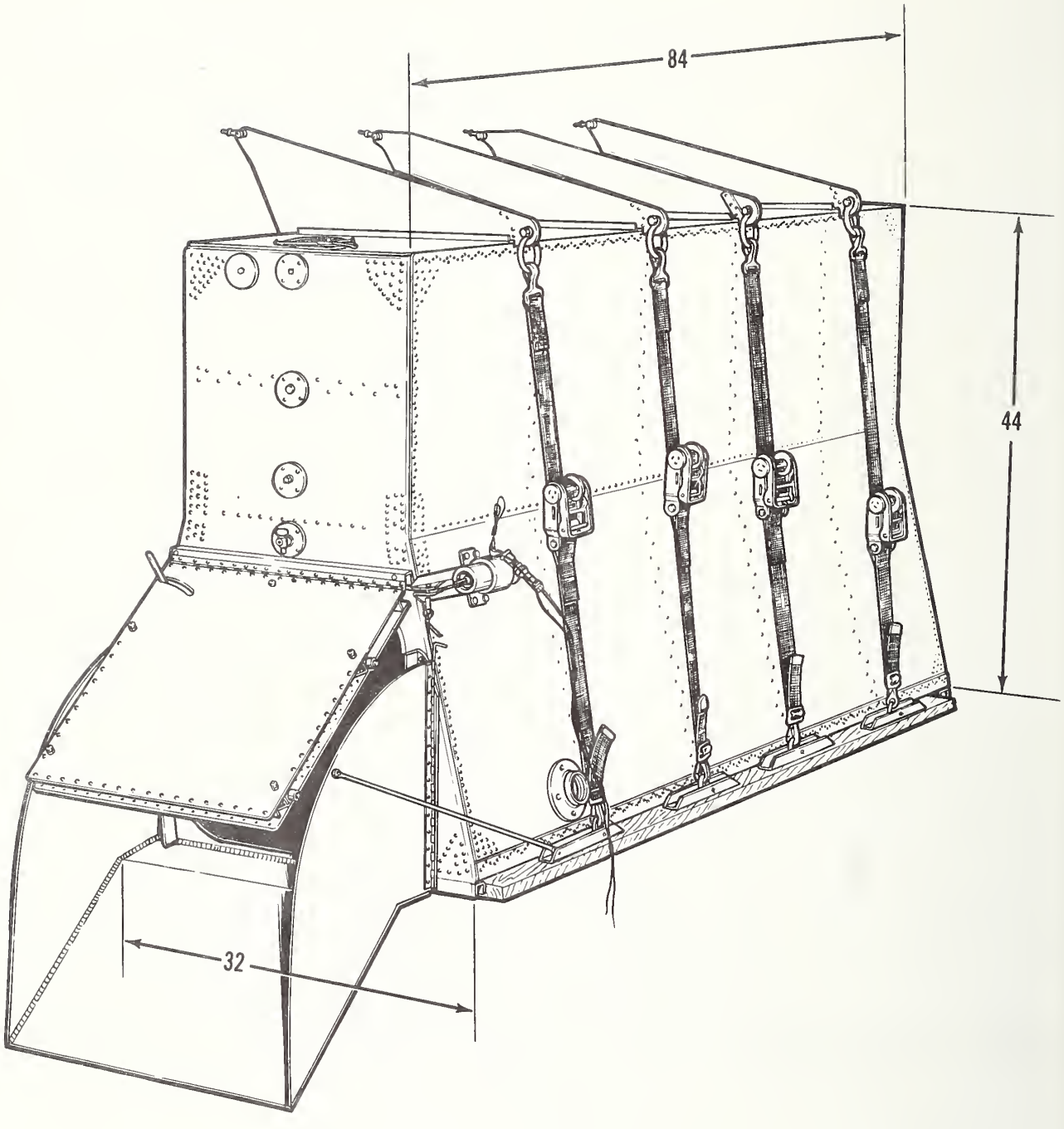
DEPARTMENT OF AGRICULTURE



AGRICULTURE—FOREST SERVICE—SAN FRANCISCO

INTRODUCTION

During the months of September and October 1963, a Bell 204B helicopter was contracted for fire-standby and training by the Angeles National Forest. In order to increase its fire fighting capabilities, the California Region financed the construction of a drop tank by a private contractor. Initial design criteria and schedules were discussed at a meeting attended by personnel from Bell Helicopter, the Forest Service, Los Angeles County, and National Helicopter Service and Engineering Company, the contractor.

Specifications as preferred by the Arcadia Equipment Development and Testing Center (see appendix I) were presented for consideration but were not wholly adopted. However, the test and evaluation phase was accepted by the Center (see appendix II and III) and is the subject of this report.

The primary objectives of these tests were to delineate drop patterns at selected airspeeds in order to judge potential fire fighting capabilities and establish criteria for possible design changes.

DESCRIPTION OF THE TANK AND INSTALLATION

The tank was constructed to fit in the open cabin area aft of the center row of seats and ahead of the firewall. The c.g. of the tank is located at station 107. Final capacity of the tank was 360 U.S. gallons.

Figure 1 - End view of tank installed in helicopter.

The tank was restrained in the helicopter at the top by four brackets bolted to the firewall and strapped to the 3/4-inch plywood platform with Aeroquip ratchet strap assemblies. This platform in turn was bolted to the cabin floor tie-down points and served to distribute the load uniformly over the deck.

The weight and balance limitations dictated that the tank c.g. not move ahead of station 107; that is, 16 inches forward of the rear cabin bulkhead, station 123. Accordingly, the tank was constructed 32 inches wide at the base so that the installed weight of 261 pounds is at the fuselage station 107. The liquid weight is at the same station, with the amount allowable depending upon the overall loading schedule and gross weight limit of 8500 pounds. This conforms to the flight manual's c.g. vs. gross weight limits for station 127 forward and station 133 aft, as approved.

Empty weight	4600 pounds
Total fuel	1040
Oil	58
	5698
* Usable load	2802
Gross	8500 pounds

Construction is conventional monocoque riveted alclad 2024-T3 sheet .080 inches thick. The perspective sketch indicates the general overall dimensions, while figure 2 shows the internal stress rods and baffles.

Figure 2 - Interior of tank.

* To include kits, pilot(s) and disposable load. This may be increased by reducing the amount of fuel carried.

The discharge chute on the right side is removable by pulling two hinge pins, so that the doors on the helicopter can be closed for ferrying. The trap on the tank is 19 inches square and is secured by four dog-type latches. It is hinged at the top and swings out when electrically or mechanically released.

Although for the tests the filling was done through a garden hose type valve, the tank will eventually be equipped with a quick-connect valve such as that used on airtankers. Because the filling attachment is at the bottom of the tank, there are no foaming or splash problems ordinarily encountered in top filling. Two lightly spring-loaded discs 6 inches in diameter are located in the top to vent the tank during drops.

Petcock fittings are spotted at the 220, 250, 300, and 360 gallon levels for determining liquid level.

TEST PROCEDURE

In order to evaluate the tank operation from the standpoint of fire fighting, the tests were planned to permit observation of the pattern dimensions and shape, as well as height and velocity of the aircraft during each drop.

Prior to these pattern studies, the in-flight stability and control effects were explored by Bell representatives for the purpose of satisfying the FAA certification for Part 8 operation. These runs were performed in a build-up manner at increasing load increments. No noticeable free-surface oscillations or adverse control effects were noted.

On October 28, 1963, pattern studies were conducted at Chino Airport on the south edge of the tie-down and taxi ramp. A clear area was selected along existing painted taxi lines 50 feet apart (laterally) and 7-foot pylons were placed 250 feet apart (longitudinally). A Hulcher sequence camera was surveyed at right angles to the line of flight for recording position and velocity. Frame rate was 10 per second.

The pylons were moved laterally between drops to provide a dry area for each run. A sequence of three frames of one of the drops is shown in figure 3.

Figure 3

A T-34 chase plane was utilized with an observer taking aerial photos of the patterns after each drop. The overall results of three drops are seen in figure 4.

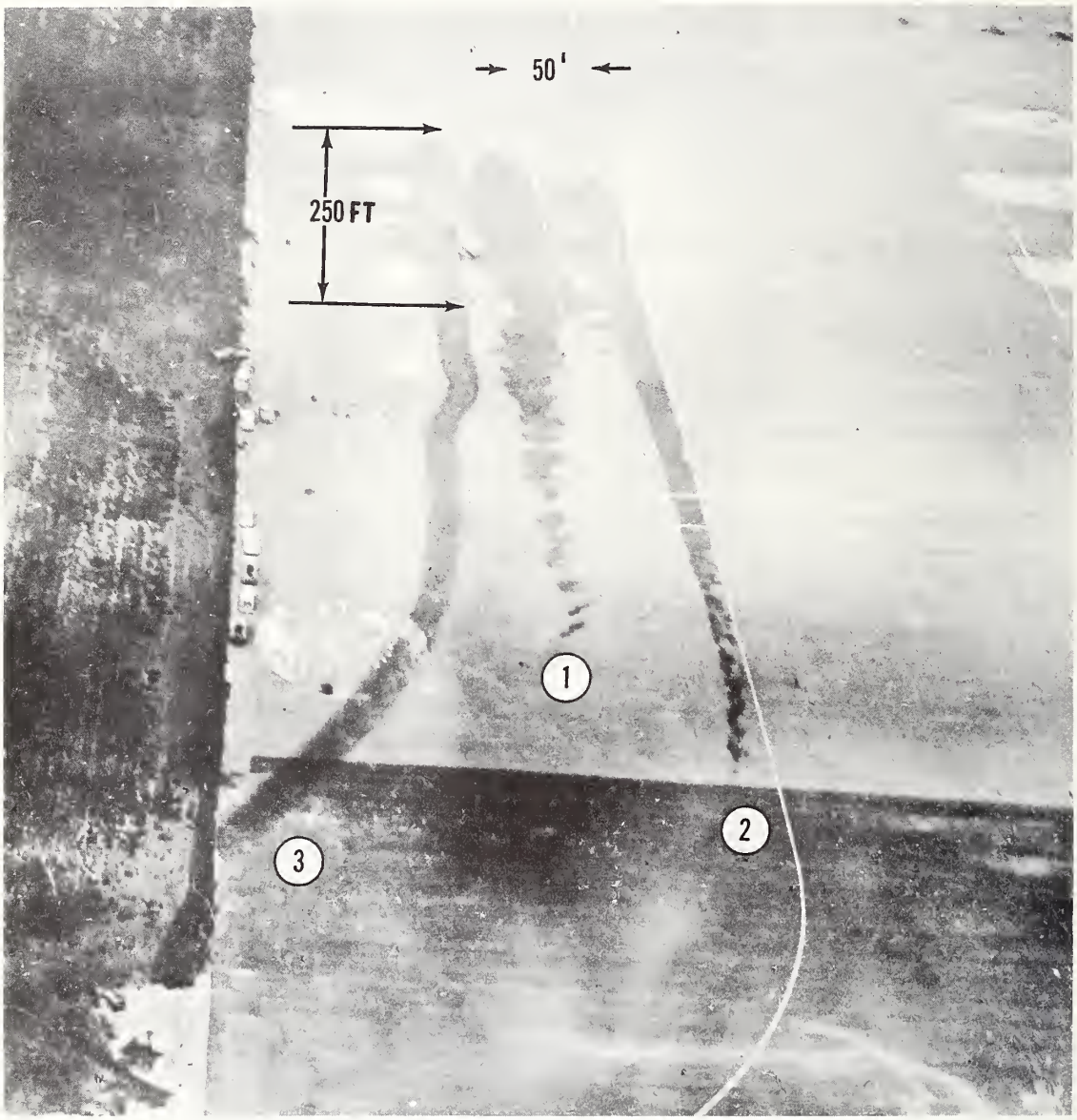
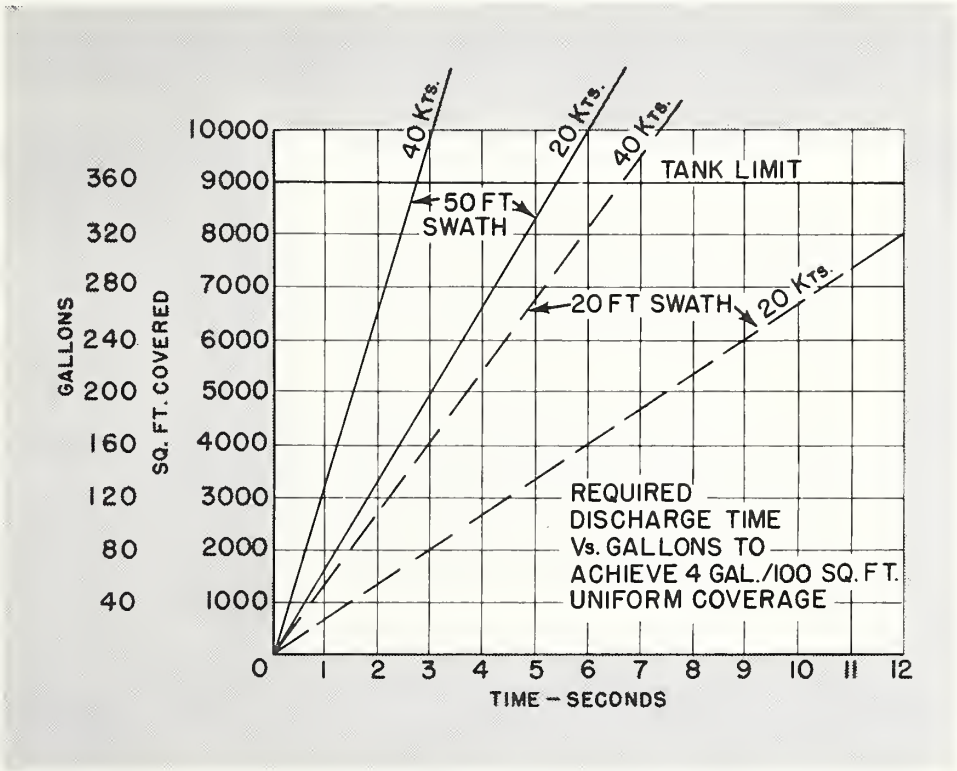


Figure 4

An electric gun camera was mounted on the right skid in an attempt to record discharge through the trap, but unfortunately a malfunction occurred and the film failed to run through the camera.

TEST RESULTS

The graph below indicates the optimum time for discharge at 20 knots airspeed based on swath widths of 50 and 20 feet, and 4 gallons per 100 square feet uniform coverage.



Discharge time averaged 12 to 15 seconds. The cut-off point was difficult to determine, since the discharge rate diminished rapidly as the tank unloaded. The only point on the graph which fits the timed performance obtained is a 20-foot swath dropped at 20 knots. This, of course, is based on a uniform discharge rate which was not obtained, and would result in a pattern about 450 feet long.

It appeared that the initial 150 gallons were discharged in the first 3 or 4 seconds because of the positive head on the liquid. When the liquid level dropped to door level it became subject to static air pressure and the remaining 200 gallons was spread out for about 10 seconds. This resulted in patterns shown in figure 4. The 40-knot drop is in the center; the 20-knot drop on the right, and the 10-knot on the left.

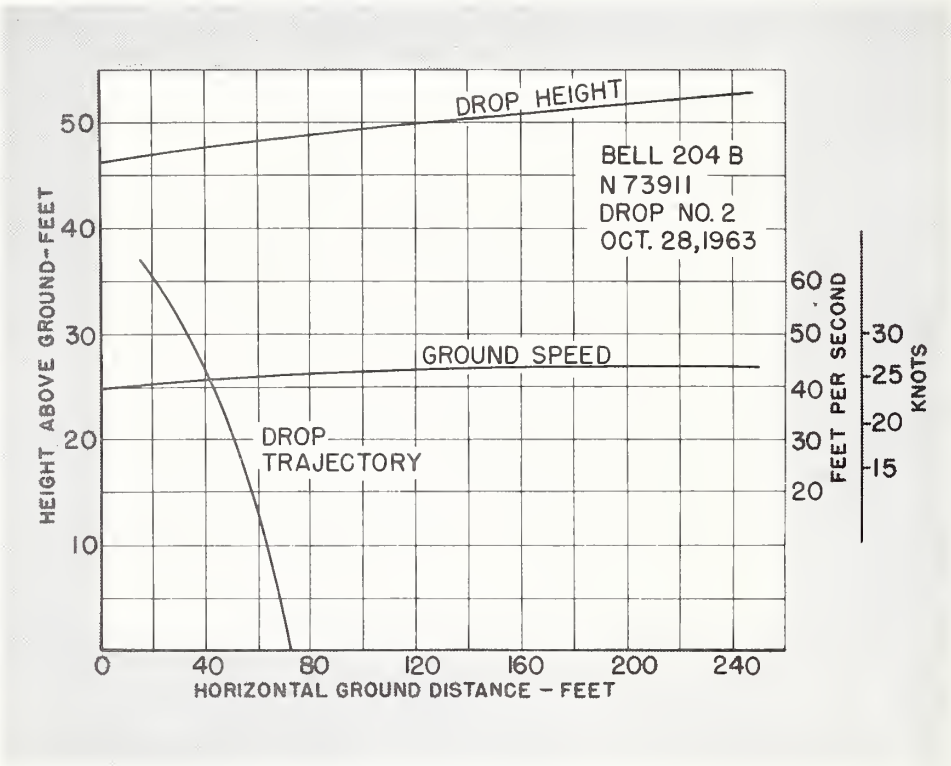
The flow rates appear to be inverse to air speeds. This is probably because the side position of the tank opening is subject to decreasing air pressure as the velocity increases, in effect "sucking" the water out at higher air speeds.

The section between the pylons, spaced at 250 feet, received the most water and the runoff was easily visible. The wet trail beyond the pylons would probably not be effective for fire control purposes.

The swaths were about 20 feet wide in each drop and the inboard edge of each swath terminated directly beneath the line of flight, hence the center line of each drop was displaced 10 feet to the right. From this it could be inferred that discharge from both sides would meet in the center and produce an effective 40-foot swath, providing, of course, that downwash effects are not severe.

The door and release mechanism functioned efficiently, and it should be added that the overall tank construction and workmanship was of high caliber.

The following graph indicates variations in velocity and height during a typical drop. Both height and ground speed increase progressively during the drop period, although speed tends to level off. It is interesting to note that the impact of liquid is about 57 feet beyond the point of release at this speed.



At 10 knots, rotor blast effects became evident on the ground.

CONCLUSIONS

The Bell 204B helicopter equipped with a 360-gallon tank offers the potential of fast, accurate delivery of water or chemicals on fire missions, plus the versatility inherent in a helicopter. But the tank, in its present form, discharges too slowly. And since the discharge rate is inverse to speed, little control is available for altering the existing patterns. The present swath width of 20 feet is too narrow.

No adverse effects were noted on maneuverability, control, or stability from the present configuration.

Because of c.g. limitations, the tank and liquid load must be on or behind station 107. This restricts the potential capacity of the tank since the full cargo space cannot be utilized.

The mechanical arrangement and functioning of the present design is excellent. The tank is easy to handle, install, and operate. The present design permits construction at minimum costs.

Air speeds below 20 knots definitely introduce rotor blast effects on the ground, which would constitute a hazard if flown directly over a fire at altitudes below 50 feet.

RECOMMENDATIONS

In order to improve the performance of the tank for fire fighting, the following measures are recommended:

1. Install a vertical baffle so as to divide the tank into equal lateral cells of approximately 180 gallons each. Remove the existing horizontal baffle to eliminate flow restrictions.

2. Install an identical door on the left side of the tank to permit discharge from one or both sides.

3. Install a watertight deck in the bottom of the tank raised in the center and tilted toward the doors so as to direct the flow outward.

4. Conduct another series of tests to determine the adequacy of performance after these modifications.

APPENDIX I

HELICOPTER "DROP TANK" SPECIFICATIONS

A. OBJECTIVES

To design and manufacture one prototype "Drop Tank" for the Bell 204-B helicopter.

B. GENERAL REQUIREMENTS

1. The production "Drop Tank" shall be developed and certificated in conformity with applicable FAA specifications, part 8.

2. Performance shall be in accordance with specifications to be developed in subsequent sections of this specifications.

3. Installation instructions and applicable performance details shall be provided with each set of equipment delivered.

C. DESIGN SPECIFICATION

1. Performance

Application Rate	2 to 4 gallons per 100 square feet
Flight Speed	20 Knots
Swath Width (ft)	25 Feet to 50 feet
Flow Rate	60 gallons per second maximum

2. Configuration

   a) The "Drop Tank" will consist of one self contained unit mounted in the cargo compartment.

   b) The tank will be constructed of aluminum due to corrosion and weight factors.

   c) The two filler openings will be in the bottom of the tank using three inch Aeroquip "Quick Disconnect" fittings. Loading shall be accomplished from either side of the helicopter.

   d) The tank shall be leak proof and will be equipped with adequate, spring loaded, vent door in the top.

e) Due to the nature of the mission and material involved no agitation shall be provided in the tank.

f) Door dimensions of the Bell 204-B dictate that the "Drop Tank" shall be easily installed and removed through a 4' x 4' opening.

g) Quick installation and removal of the system should not require time in excess of 5 to 7 minutes, involving no winches or other equipment.

h) In keeping with (g) above, all attach points shall be of the "Quick Disconnect" type.

i) The tank shall be equipped with a visual sight gauge visible to the pilot during flight operations.

j) With the present load capabilities of the Bell 204-B set at 3000 pounds the "Drop Tank" would carry 300 gallons of fire suppressant material. Contemplating increase capability and possible foaming during loading, it is estimated the tank should have a capacity of 450 gallons.

k) To eliminate the hazard of overloading the tank shall be equipped with adequate overflow facilities.

l) The base of the "Drop Tank" will be skid construction to facilitate installation and removal. The skid base will also act to prevent damage to the kit when stored on the ground or being transported which is contemplated in a standard 1/2 ton pickup truck.

m) To increase the capability of the Bell 204-B for initial attack missions the tank of the "Drop Tank" shall consist of four compartments of 75 gallons each. The pilot shall be able, in flight, to select and drop the following amounts 75 gallons, 150 gallons, 225 gallons, and 300 gallons. Actuation of the drop doors will be electric, controlled by the pilot, mounted on the control stick. Consideration is being given to the fact that manual closing of the drop doors prior to loading is of no disadvantage to the mission. The electrical actuation system for the drop doors will have a mechanical back up system incorporated.

n) Dumping will be accomplished through "Drop Chutes" located on each side of the helicopter. For experimental purposes it is suggested the "Drop Chutes" be rotatable through 90 degrees from straight down to straight aft. Rotation may be accomplished on the ground through manual means.

3. Design Features

a) The "Drop Tank" shall have an overhaul free life equivalent of at least 100 continuous hours.

b) The installation weight of the "Drop Tank", including accessories, shall not exceed 300 pounds.

c) To maintain complete versatility of the Bell 204-B helicopter the "Drop Tank" will be a complete self contained unit quickly installed and removed.

d) The "Drop Tank" shall not require storage racks for ground storage or transportation.

MEMORANDUM

Burbank, California
October 9, 1963

Subject: Bell Model 204B Retardant Tank Program

Persons in Attendance: Cal Ferris and M. L. Sutter, U.S.F.S., San Francisco 11; W.R.C. Beaty, U.S.F.S., Pasadena; Herb Shields, U.S.F.S., Arcadia.

Chief Frank R. Hamp and Roland Barton, L.A. County Fire Dept.

C. R. Ritchey and Bud Nelson, L.A. City Fire Dept.

Richard H. Hart and Harry Hauss, National Helicopter Service & Engineering Company, Glendale, Calif.

Tom Patterson, Helicopter Mechanic Services, Van Nuys, Calif.

Jack Bell, Test Pilot; Sam Brindley, Project Engineer; and A. L. Fornoff, Bell Helicopter Company

A meeting was called at Bell Helicopter Company's office on October 9 for the purpose of discussing the basic design for a Model 204B Retardant Drop Tank. Preliminary studies were conducted to ascertain the location for placement of the Retardant Drop Tank.

From the studies conducted, it became obvious that locating the Tank in the passenger-cargo compartment of the helicopter would be best suited.

The volume of the tank proposed is estimated to be 400 U. S. gallons. The c.g of the tank would be at Station 107. The approximate dimensions of the tank would be 45" high, 32" wide at the base and 84" long The top of the tank width would be 24".

The tank will be restrained in the helicopter by using the four top bulkhead attach fittings at Station 123, four of the seat belt attachments fitted on the 123 bulkhead and with Nylon web straps over the tank down to floor structure forward of tank. The helicopter floor structure would be reinforced by adding a 3/4" plywood or similar structural decking, which would be secured to the floor by bolting into the stud locations on eight of the cargo tiedown fittings. This "decking" would have eye bolt inserts that would be the end fittings for the hold down straps on the tank. This "decking" would not interfere with the installation of either the 5-passenger or 3 passenger seat.

When installed, the tank size would be such that the cabin doors could be closed for flight. When the tank installation is made, the rear seats may be folded and stowed on the aft cabin bulkhead and the 3-passenger intermediate seat may remain installed.

The design objective will be to provide for quick installation or removal of the tank installation. The following features will be incorporated for securing the tank:

At the seat belt attachments, a turnbuckle type snap latch will be provided. At the top cabin bulkhead attachments, "Pip" pins will be used to secure aliminum arms in four places which will lie on top of the tank with the forward part of these arms secured to the deck by means of straps with ratchet tension adjustment.

The complete installation can be made without the use of tools.

The discharge end of the tank will be designed so that possible development changes to the discharge mechanism and nozzle can be made with a minimum effort and expense at a later date.

The filler mechanism will consist of a 1½" diameter pipe flange located at the lower part of the discharge end of the tank. The intent of this fitting is that various quick release type couplings could be employed.

The top surface of the tank will incorporate two spring loaded air vents to facilitate discharge of the tank. In addition, a spring loaded vent will be employed on the righthand end of the tank near the top to bleed off air in the tank during the filling operation. This vent shall also serve as overflow vent should the tank be overfilled. Discharge from the overflow vent should be directed so that it would discharge free of the airframe.

A means for determining the quantity level will be provided by installing pipe flanges for petcock installations on the righthand end of the tank, from 200 gallons to full, in 25-gallon increments.

Initially we will provide a chute at the tank discharge outlet which will deflect the liquid beyond the structure of the aircraft. This chute shall be designed in such a manner that modifications can be made at minimum effort and expense, and in addition, this chute will be made removable to provide closure of the righthand cabin door.

The discharge door will be designed for an approximate dimension of two square feet and will be located at the lower extremity of the righthand side of the tank and will be secured in place by cam locking mechanism with four locking pins. This door will be actuated, electrically and mechanically, from the Pilot's station. The electrical release shall be considered primary and shall be actuated from a button on the cyclic control stick.

The discharge door will be hinged at the top and will open outward with a device incorporated to adjust the extent of the opening. The inner surfaces of the door frame will be faired to minimize flow turbulence.

The floor of the tank will be fabricated as a flat surface initially. Should actual experiences indicate that a sloping floor is desirable,

further development testing can be conducted by molding a floor inside the tank with the desired slope, without disassembly and jeopardizing the structure of the tank system.

The basic design intent will be such that an S.T.C. may be obtained on the tank and its installation. Stress calculations, effect on aerodynamic control, weight and balance, will be provided.

Certification will be made by the Equipment Development Center of the U. S. Forest Service, under Part 8 Regulations.

All persons who attended this meeting concurred with the basic design as outlined above.

The above design comments and information is considered authority for National Helicopter Service & Engineering Company to proceed with the building of the tank and controls. It is estimated that the tank will be completed on October 21, 1963, ready for flight test

A flight test program will be prepared by the U. S. Forest Service and is expected to start on the morning of October 22, 1963.

A. L. Fornoff

A. L. Fornoff
Chairman

BELL HELICOPTER COMPANY

INTER-OFFICE MEMO

Date October 22, 1963.

TO: A. L. Formoff

Copies to: Bud Rawlins, Jack Bell, Floyd Carlson

Subject. Retardant Drop Tank

The purpose of this outline is to present an orderly and complete test program for evaluation of the fire retardant tank installation on Model 204B, Serial #2002

The approximate volume of this tank is 400 gallons and will be installed in the cabin area with the C.G. located at Station 107.

The ultimate utilization of this tank will be for the aerial application of various liquids to retard or extinguish brush and forest fires. The following program is intended to provide a careful buildup type series of tests which will enable the pilot to evaluate the effect on helicopter controllability caused by sloshing of liquids throughout the flight regime and any adverse effect caused by sudden dumping of the liquid load.

The second phase of this test program is intended to present a development phase for evaluating various nozzles and discharge openings to obtain an optimum distribution pattern of the retardant liquid.

The estimated flight hours indicated at each test condition are based on the assumption that the drop zone will be located in the immediate vicinity of the heliport It is also recommended that a heliport with suitable emergency landing facilities be used for this program in the event malfunction of the aircraft/tank installation would necessitate an emergency landing.

PHASE I

A. Fit tank to aircraft and functionally check operation of electrical and mechanical door release - dry.

B. Fit tank to aircraft and functionally check operation of electrical and mechanical door release with 200 gallons water in tank

Flight evaluate for slosh with 100 gallons in the following maneuvers:

30 min

1. Stabilize sideward flight
2. Flare following sideward flight
3. Rapid acceleration
4. Quick stop from forward flight
5. Stabilize turn at cruise
6. Yaw at cruise (various increments)
7. Slip at cruise.
8. Drop 100 gallon load at 60 kts. cruise.

30 min D. Repeat "C" at 200 gallons.
30 min E. Repeat "C" at 300 gallons.

F Evaluate 300 gallon drop at various cruise air speeds:

1. 20 kts.
24 min. 2. 40 kts.
3. 80 kts.
4. 100 kts.

G Evaluate 100 gallon drop during descent at 60 kts:

18 min. 1. 15 psi torque.
2. Full autorotations.

PHASE II

A. Evaluate degree of door opening on discharge gate and pattern:

Time Un- known 1 33% open.
2 67% open.
3. 100% open.

B. Evaluate various discharge nozzle designs to achieve optimum spray pattern

C. Evaluate drops with various density liquids in optimum configuration as determined in PHASE II, A and B.

Sam Brimdley
204B Project Engineer

Jack Bell
204B Flight Test Pilot